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# Preliminary stem diameter, height, and volume losses in grand fir during western spruce budworm outbreaks, New MDWS R. D., Payette N. F.

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## Introduction

Effects of western spruce budworm outbreaks on grand fir have not been examined intensively in Idaho. To obtain data on effects of current and previous budworm outbreaks, a cooperative study was conducted by USDA-Forest Service personnel from the Pacific Southwest Forest and Range Experiment Station, the Payette National Forest and Forest Insect and Disease Management, Intermountain Region, in August 1978. The study was conducted at two sites in the Boulder Creek drainage, New Meadows Ranger District, Payette National Forest. This area has been exposed to the three most recent budworm outbreaks: 1920's, 1950's, and 1970's.

## Methods

Two stands were selected for sampling based on the following criteria: (1) reportedly defoliated during western spruce budworm (WSB) outbreaks in the years 1922-1930 (Johnson and Denton), 1952-1955 2/, and 1969-1977 3/; (2) containing a high proportion of grand fir (GF) at least 80 - 100 years old and thus pole-sized during the 1920's. One stand, Bear Wallow (BW) had been subjected to an "improvement cut", the other stand, Bullhorn Creek (BH), was virgin.

Twenty firs were selected at random from each plot as follows: each plot was divided into one-chain-wide strips. The strips were numbered and selected for survey by random draw. Within each selected strip, the first four GF over 14" dbh were selected as sample trees.

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1/ Research Entomologist and Pathologist, respectively, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.

2/ Furniss, M. M. An appraisal survey of spruce budworm damage on parts of the Boise and Payette National Forests in Southern Idaho. November 1954. Unpub. report on file, Intermountain Forest and Range Experiment Station, Ogden, Utah.

3/ Ollieu, M., L. Livingston, and W. Bousfield. Impact of defoliation by spruce budworm. Boise and Payette National Forests and Intermingled Federal, State, and private lands, 1977. Unpub. report on file, USDA, Forest Service, Forest Insect and Disease Management, Boise, Idaho.

After felling, the lengths of all exteriorly visible internodes were measured. Each stem deformity (fork, spike, crook) was examined and the following data taken: diameter at pont of topkill, year of topkill (number of annual rings formed since injury), length of any decay column arising from topkill. Also, lower (stump), mid (mid-bole), and upper (upper-bole) sample disks were collected for radial increment measurements.

For both radial and height increments, periodic increments, when series of obviously narrow rings or shortened internodes were formed, was compared with periodic increments over the same number of immediately preceding years. The difference between these periodic increments was considered to be an increment reduction or "loss". It was uncertain as to whether the outbreaks, particularly the earlier ones, had been detected in their initial year. Also, effects of budworm outbreaks on the growth of host trees typically persist for at least three years after the outbreaks subside. Consequently, to insure inclusion of all WSB-related topkilling and growth losses, losses were attributed to WSB which occurred within one year before and three years after reported outbreak periods, i.e., 1921-1933, 1951-1958 1/, and 1968(9)2/-1978.

Cubic foot volume losses were obtained as follows: stem volume was calculated by assuming the tree consisted of two logs bound by the upper, mid, and lower sample disks. (The diameter of the upper sample disks averaged just over four inches, the usual top diameter for cubic foot volume tables.) Volume was calculated assuming each log was a cylinder, with a radius equaling the average of radii at the upper and lower log ends. In addition to log volumes calculated from log measurements, or "observed" volumes, increment losses were added to the log's dimensions to calculate "expected" volume had no losses occurred. The difference between expected and observed volumes was considered to be the volume loss attributable to increment reduction during the outbreaks, combined with volume loss due to the decay or deformity associated with each topkill. When decay was absent, the volume loss due to the stem deformity was calculated using the diameter at the point of injury, and assuming the length of log lost was two feet. If the decay was associated, length of the decay column and the average diameter of the affected bole, estimated from the diameter measured at point of injury were used. When a decay volume loss exceeded 67 percent of the log's volume, the entire log was considered a cull loss, and any loss due to increment reduction in that log during the outbreak when topkill occurred was ignored.

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1/ This outbreak was terminated by DDT spray projects in 1955-1956. Furniss, M. M. Entomological aspects of the 1955-56 Southern Idaho spruce budworm control projects. Unpub. reports on file, Intermountain Forest and Range Experiment Station, Ogden, Utah.

2/ The recent outbreak was first detected at BW in 1969, at BH in 1970; thus, losses were attributed to budworm if they occurred after 1968 and 1969, respectively.

Size and Age of Sample Trees. On the average, trees sampled at BH were larger and older than those sampled at BW. The dimensions and age, as well as expected volumes calculated under the assumption that no increment reductions attributable to WSB had occurred, are given in Table 1.

## Results

Incident and Type of Top Injury. Ninety (90) top injuries were found in the 40 sample trees, 45 on each plot. Over half (51) of the injuries had a dead spike or broken top issuing from the point of injury. An embedded dead top was found in an additional 24 injuries. Thus 83 percent (75) of the injuries involved dieback extending a considerable distance down the stem. The remaining 14 (17 percent) injuries were crooks, forks, and multiple tops, in which old dead tops were not found, either externally or internally (embedded) in the stem. Dieback in these cases must have been more limited, probably involving only the bud or the current year's growth. All but two of the trees had recognizable top injury of some sort, with the number of topkills in individual trees ranging up to seven.

Fifty-eight (58) of the top injuries were attributable to WSB, 33 at BW, and 25 at BH. Thirty-two (32) injuries could not be attributed to WSB due either to the year in which they occurred (28), or because the year of injury could not be established (4).

The observed incidence of topkilling was somewhat higher at BH than at BW during the period 1921-33 (Table 2). Fewer topkills were found, with little interplot difference, in 1951-58. During 1968-78, considerable topkilling was found at BW, and not at BH. Over all three periods, the sample trees had each been topkilled an average of one to two times. Only topkills attributable to the outbreaks will be discussed further.

Eighteen (18) trees had decay associated with topkill. A total of 28 topkill injuries had advanced decay associated with them. Of these, only one was in the nonmerchantable stem. About 60 percent (19) of these was associated with topkill attributable to budworm. Decay columns ranged from those 2 to 3 feet long to one that resulted in cull of the entire tree (Tree No. 11, BH). Culture and identification of causative fungi are under way; results will be presented later.

Diameter Losses. Diameter losses (stump level) were similar on the plots (Tables 3, 4) despite the greater average dbh of the BH trees. The total diameter loss attributable to budworm averaged about two inches, over two-thirds of which occurred during the years 1921-1933. Nearly all trees had diameter losses during this period but only three trees registered radial increment reduction during 1951-1958. The highest diameter loss in any tree totaled 5.4 inches.

Height Losses. Losses due to internode shortening were higher than those due to decay or deformity during the two latest outbreaks, while the reverse was true for the earliest outbreak, largely because internodes formed during the latter were not measured as they were no longer externally visible (Tables 3, 4). Total height loss in individual trees ranged from 0 to 57.5 feet, the latter due to topkill-associated decay. Total height loss averaged 9.2 feet at BW, and 12.1 feet at BH. However, internode shortening accounted for most of the loss at BW, while decay or deformity were primarily responsible at BH.

Volume Losses. Volume losses due to increment reduction and cull caused by decay or deformity are given in Tables 3 and 4 for the stem below the upper sample disk (average 4-inch top). On both plots, the bulk of the loss occurred in 1921-1933, due equally to increment reduction and decay or deformity at BH, but primarily to the former at BW. Only small losses resulted from the period 1951-1958. An average of about 5 to 7 cubic feet per tree has been lost in the period 1968-1978 due entirely to increment reduction with no decay or deformity loss yet developing. The relatively high volume losses during 1921-1933 probably resulted from the longer outbreak period, and elapsed period for decay development, as well as the greater stem diameters involved in cull "buckouts".

Total volume loss over all the outbreaks averaged almost twice as high at BH (37.0 ft.$^3$/tree) as at BW (22.2 ft.$^3$/tree). These losses are expressed as a percentage of expected tree volumes at the bottom of Tables 3 and 4. Because of tree size differences on the plots, the percentage of the total stem volume lost over all periods averaged about the same (24.8 percent at BW, 25.3 percent at BH). However, increment reduction was more important than decay or deformity at BW, while at BH these were equally important. Volume losses in individual trees ranged from 3.1 ft.$^3$ and less than 3 percent of tree volume, up to 146.2 ft.$^3$ more than 84 percent of tree volume. The largest cubic-foot, and percentage, losses occurred for trees in which the entire lower log was culled to decay.

Losses in Topkilled Vs. Untopkilled Trees. Losses in trees topkilled during each of the outbreaks are compared with those in trees not evidencing topkill during the outbreak in Tables 5 and 6. (No comparisons were possible, as no trees were topkilled at BH during 1969-1978.) Also, total losses over all three outbreaks, for trees topkilled during any of the outbreaks, are compared with losses found in trees not evidencing topkill during any of the outbreaks.

During each outbreak at BW, topkilled trees averaged slightly higher stump diameter losses than untopkilled trees. This also occurred at BH during 1921-1933. Also, at BW total diameter loss over all three outbreaks was slightly higher in trees topkilled at least once during the three outbreaks, compared to trees not evidencing topkill during any of the outbreaks. (Only one tree at BH met the latter condition, making this comparison inadequate). However, stump diameter loss differences do not appear managerially significant, and may not be even statistically significant; statistical tests will be made in the final report. The largest difference was only .7 of an inch (BW, 1951-1958).

Differences in stem length loss appear to be more managerially significant, especially when "buckouts" for decay or deformity are combined with height increment losses. On the average, trees topkilled during 1921-1933 lost 14.5 feet more than untopkilled trees at BW, and 8 feet more than untopkilled trees at BH. Over all three outbreaks, these height loss differences averaged 8.5 feet at BW and 11.2 feet at BH.

Differences in volume losses appear even greater, except for 1951-1958 at BH where the three topkilled trees had no stump diameter losses and the losses in stem length were above the merchantable stem and so not included in the volume losses.

On both plots, the largest volume losses were associated with topkilling during 1921-1933, averageing 3 to 4 times greater than losses in untopkilled trees. Several factors may be responsible for this large difference. This outbreak was of longer duration than the others, and was accompanied by severe drought years; the final report will analyze this relationship more closely. Also, there has been a longer period of time for decay to develop from the killed top; hence, the decay cull was higher for this outbreak. Also, decay and deformity caused by topkill during this period results in "Buckouts" in the lower or butt log, causing considerable volume loss.

Table 7 compares average percentage volume losses in topkilled vs. untopkilled trees when trees from both plots were combined and placed in classes based on their DBH and age when sampled. Due to the factors already discussed, losses in all classes were generally higher in topkilled, compared to untopkilled trees. During 1921-1933, percentage volume losses were highest, averaging 30 to 40 percent, in topkilled trees currently 17 to 22 inches in dbh and 121 to 150 years of age. Fifty years ago, during the outbreak, these trees were 70 to 100 year-old, large pole, or younger sawtimber, sized trees, probably 12 to 16 inches dbh. Losses were low during 1951-1958, but were slightly higher in trees presently in the same dbh and age class as that cited above. However, in 1951-1958, these trees were 100 to 125 years old and probably 14 to 18 inches in dbh.

Percentage volume losses during 1968(9)-78 have been highest in the youngest trees sampled - 90 to 120 years old and 14 to 15 inches dbh, and lowest in the largest and oldest trees sampled. This result reinforces the result obtained from the earliest outbreak, that the young sawtimber-sized trees suffer higher percentage losses than the old-growth trees.

The results indicate that topkilling of young pole-sized or sawtimber grand fir by spruce budworm evenually causes considerable volume loss at rotation age, while topkilling of mature trees results in minor loss of merchantable volume.

Table 1. Characteristics of grand firs sampled on two plots, New Meadows R.D., Payette N.F., for stem effects of western spruce budworm outbreaks.

| Characteristic | Bear Wallow Ave. (Range) | Bullhorn Creek Ave. (Range) |
|---|---|---|
| DBH (in.) 1/ | 18.0 (14-24) | 24.6 (16-38) |
| Height (ft.) 2/ | 77.9 (40.0-101.0) | 88.7 (35.0-129.0) |
| Volume (ft.) 3/ | 91.8 (28.8-222.5) | 156.9 (42.0-360.0) |
| Age (years) 1/ | 123 (90-154) | 192 (137-242) |

1/ Stump
2/ Total, stem
3/ Expected had no increment reduction attributable to WSB occurred.

Table 2. Incidence of stem injuries attributed to topkilling during western spruce budworm outbreaks - grand firs, New Meadows R. D.

| Topkill 1/ | 1921-1933 | 1951-1958 | 1968-1978 | TOTAL 2/ |
|---|---|---|---|---|
| | | Bear Wallow (20 trees) | | |
| Percent | 55 | 20 | 75 | 95 |
| No./Tree, Avg. | 0.6 | 0.2 | 0.9 | 1.7 |
| (Range) | (0-2) | (0-1) | (0-2) | (0-3) |
| | | Bullhorn Creek (19 trees) | | |
| Percent | 63 | 16 | 0 | 68 |
| No./Tree, Avg. | 1.1 | 0.2 | 0.0 | 1.3 |
| (Range) | (0-7) | (0-1) | 0 | (0-7) |

1/ Crook, spike of fork.
2/ Percentage of sample trees topkilled during any of the three outbreaks. Average and range in total number of topkills/tree over all three outbreaks.

Table 3. Stem losses attributed to western spruce budworm outbreaks in grand firs - Bear Wallow

| Type 1/ | 1921-1933 | 1951-1958 | 1967-1978 | Total |
|---|---|---|---|---|
| | AVERAGE (RANGE) | | | |
| | Stump diameter (in.) | | | |
| IR | 1.52(0-3.46) | .11(0-2.13) | .56(0-1.50) | 2.19(0-4.89) |
| | Stem length (ft.) 2/ | | | |
| IR | 9.9(5.9-13.5)* | 1.5(0-16.2) | 4.8(0-16.3) | 7.8(0-24.1) |
| D/D | 1.2(0-4.5) | .2(0-2.0) | 0 | 1.4(0-6.5) |
| Total | 2.7(0-13.5) | 1.7(0-16.2) | 0 | 9.2(1.1-24.1) |
| | Volume ($ft^3$) 3/ | | | |
| IR | 11.6(1.9-37.6) | .6(0-7.5) | 6.6(0-26.0) | 17.5(3.1-44.2) |
| D/D | 5.6(0-90.2) | .1(0-10) | 0 | 5.7(0-90.8) |
| Total | 16.8(2.0-91.1) | .7(0-8.1) | 6.6(0-26.0) | 22.2(3.1-92.2) |
| | Volume (%) 4/ | | | |
| IR | 12.4(2.4-37.2) | .7(0-6.3) | 8.7(0-37.6) | 20.2(2.5-43.4) |
| D/D | 5.3(0-76.3) | .1(0-1.3) | 0 | 5.4(0-76.8) |
| Total | 17.4(2.4-77.1) | .8(0-6.8) | 8.7(0-37.6) | 24.8(2.5-78.0) |

1/ IR = increment reduction; D/D = decay or deformity; Total = IR+D/D except some IR not included for culled logs.
2/ IR for entire stem; D/D below average 4 inch top.
3/ Below average 4 inch top.
4/ Percentage of volume expected had no increment reduction occurred, below 4 inch top.
* Some or all of internodes for period not measurable.

Table 4. Stem losses attributed to western spruce budworm outbreaks in grand firs - Bullhorn Creek.

| Type [1] | AVERAGE (RANGE) 1921-1933 | 1951-1958 | 1967-1978 | Total |
|---|---|---|---|---|
| | Stump diameter (in.) | | | |
| IR | 1.29(.31-2.99) | .13(0-1.54) | .39(0-1.26) | 1.81(.31-5.40) |
| | Stem length (ft.) [2] | | | |
| IR | * | 1.4 (0-14.5) | 1.3(0-6.8) | 2.7(0-20.0) |
| D/D | 9.2(0-55.0) | .2(0-2.0) | 0 | 9.4(0-55.0) |
| Total | 9.2(0-55.0) | 1.6(0-14.5) | 1.3(0-6.8) | 12.1(0-57.5) |
| | Volume ($ft^3$) [3] | | | |
| IR | 15.6(0-48.2) | 1.5(0-12.3) | 5.1(0-18.2) | 21.7(3.4-66.4) |
| D/D | 16.6(0-145.1) | .04(0-.5) | 0 | 17.4(0-145.1) |
| Total | 31.6(1.2-145.1) | 1.7(0-12.3) | 5.1(0-18.2) | 37.0(3.4-146.2) |
| | Volume (%) [4] | | | |
| IR | 8.6(0-24.3) | .9(0-6.4) | 4.0(0-10.2) | 13.2(3.6-29.5) |
| D/D | 12.7(0-83.7) | .04(0-.6) | 0 | 13.5(0-83.7) |
| Total | 21.2(1.5-83.7) | 1.0(0-6.4) | 4.0(0-10.2) | 25.3(3.6-84.3) |

1/ IR = increment reduction; D/D = decay or deformity; Total = IR+D/D except some IR not included for culled logs.
2/ IR for entire stem; D/D below average 4 inch top.
3/ Below average 4 inch top.
4/ Percentage of volume expected had no increment reduction occurred, below 4 inch top.
* Some or all of internodes for period not measurable.

Table 5. Average stem losses in grand firs topkilled (TK), or untopkilled (UTK) during western apruce budworm outbreaks, by type of loss - Bear Wallow plot.

| | AVERAGE LOSSES | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1921-1933 | | 1951-1958 | | 1967-1978 | | Total | |
| | TK | UTK | TK | UTK | TK | UTK | TK[5/] | UTK |
| No. trees | 11 | 9 | 4 | 16 | 15 | 5 | 19 | 1 |
| Diameter (in) [1/] | 1.55 | 1.48 | .71 | .00 | .69 | .17 | 2.31 | 3.46 |
| | Length (ft.) [2/] | | | | | | | |
| IR | 11.9* | 5.9* | 4.8 | 0.7 | 4.9 | 4.5 | 8.1 | 1.1 |
| D/D | 2.2 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 |
| Total | 14.1* | 5.9* | 5.8 | 0.7 | 4.9 | 4.5 | 9.6 | 1.1 |
| | Volume ($ft^3$) [3/] | | | | | | | |
| IR | 14.1 | 8.5 | 2.1 | 0.3 | 7.2 | 5.0 | 17.1 | 19.3 |
| D/D | 10.1 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 6.9 | 0.0 |
| Total | 24.0+ | 8.5 | 2.5 | 0.3 | 7.2 | 5.0 | 22.4+ | 19.3 |
| | Volume (%) [4/] | | | | | | | |
| IR | 15.3 | 8.9 | 1.9 | 0.4 | 9.2 | 7.1 | 20.5 | 13.8 |
| D/D | 9.6 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 6.0 | 0.0 |
| Total | 24.4+ | 8.9 | 2.4 | 0.4 | 9.2 | 7.1 | 25.4+ | 13.8 |

1/ At stump.
2/ Increment reduction (IR) in entire stem, decay, or deformity buckouts (D/D) below upper sample disk average 4 in. diameter.
3/ Below upper sample disk.
4/ Percentage of volume expected had no increment reduction occurred, below upper sample disk.
5/ Topkilled during any of the 3 outbreaks.
* Internodes measurable in 1 TK and 2 UTK trees only.
\+ Increment loss ignored in one log culled due to decay associated with budworm topkill.

Table 6. Average stem losses in grand firs topkilled (TK), or untopkilled (UTK) during western spruce budworm outbreaks, by type of loss - Bullhorn Creek plot

| | AVERAGE LOSSES | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1921-1933 | | 1951-1958 | | 1967-1978 | | Total | |
| | TK | UTK | TK | UTK | TK | UTK | TK 5/ | UTK |
| No. trees+ | 12 | 7 | 3 | 16 | 0 | 19 | 13 | 6 |
| Diameter (in) 1/ | 1.40 | 1.11 | .00 | .15 | - | .39 | 1.88 | 1.68 |
| | Length (ft.) 2/ | | | | | | | |
| IR | * | * | 4.8 | 0.8 | - | 1.3 | 2.7 | 2.7 |
| D/D | 14.5 | 0.0 | 1.3 | 0.0 | - | 0.0 | 11.2 | 0.0 |
| Total | 14.5 | 0.0 | 6.1 | 0.8 | - | 1.3 | 13.9 | 2.7 |
| | Volume ($ft^3$) 3/ | | | | | | | |
| IR | 18.2 | 11.0 | 0.0 | 1.8 | - | 5.1 | 24.3 | 16.2 |
| D/D | 26.3 | 0.0 | 0.2 | 0.0 | - | 0.0 | 25.4 | 0.0 |
| Total | 43.7≠ | 11.0 | 0.2 | 1.8 | - | 5.1 | 46.6≠ | 16.2 |
| | Volume (%) 4/ | | | | | | | |
| IR | 9.0 | 7.8 | 0.0 | 1.1 | - | 4.0 | 13.6 | 12.2 |
| D/D | 20.1 | 0.0 | 0.2 | 0.0 | - | 0.0 | 19.7 | 0.0 |
| Total | 29.0≠ | 7.8 | 0.2 | 1.1 | - | 4.0 | 31.3≠ | 12.2 |

1/ At stump.
2/ Increment reduction (IR) in entire stem, decay, or deformity buckouts (D/D) below upper sample disk average 4 in. diameter.
3/ Below upper sample disk.
4/ Percentage of volume expected had no increment reduction occurred, below upper sample disk.
5/ Topkilled during any of the 3 outbreaks.
* Internodes not externally visible and thus not measurable.
\+ One sample tree discarded--entire stem cull--decay not attributable to budworm.
≠ Increment reduction ignored in several logs culled due to decay associated with budworm topkill.

Table 7. Average percentage volume losses in topkilled (TK) and untopkilled (UTK) grand firs attributed to western spruce budworm outbreaks on both plots--by dbh and age class.

| | VOLUME LOSS (%) [1] Ft. [3] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DBH Class | 1921-1933 | | 1951-1958 | | 1967-1978 | | Total [2] | |
| (in.) | TK | UTK | TK | UTK | TK | UTK | TK | UTK |
| 14-16 | 20.3 | 5.6 | --[3] | 0.5 | 12.8 | 9.8 | 27.9 | 9.9 |
| 17-22 | 37.9 | 8.6 | 1.7 | 0.7 | 6.5 | 5.1 | 27.9 | 9.7 |
| 23-28 | 28.1 | 17.0 | -- | 0.9 | 3.2 | 3.8 | 31.2 | 29.5 |
| 29-38 | 15.1 | 8.7 | 0.1 | 1.1 | -- | 1.9 | 19.1 | 9.2 |
| Age Class (yrs.) | | | | | | | | |
| 90-120 | 15.4 | 8.7 | 1.3 | 0.6 | 9.1 | -- | 23.0 | -- |
| 121-150 | 32.2 | 8.3 | 2.1 | 1.0 | 4.1 | 2.4 | 24.7 | 11.8 |
| 151-200 | 21.8 | 16.7 | 0.0 | 1.4 | 1.8 | 13.4 | 30.7 | 9.9 |
| 201-242 | 27.4 | 11.3 | 0.1 | 1.0 | -- | 3.2 | 30.2 | 13.8 |

1/ Percentage of volume expected had no increment reduction attributable to WSB occurred.
2/ Topkilled during any of the 3 outbreaks.
3/ No trees in this category.